

Claims

[c1] 1. A starter for an internal combustion engine, said starter comprising a DC electrical motor having an output shaft in starting arrangement with a shaft of the engine for starting the engine said motor being comprised of cooperating, relatively rotatable permanent magnet and coil winding elements, said permanent magnet element being comprised of circumferentially spaced permanent magnets of opposite polarity, said coil winding element being comprised of circumferentially spaced magnetic pole cores around which electrical coils are wound, said cores having ends in facing relation to said permanent magnets, said motor having reduced vibration after engine starting by at least one of reducing the cogging torque of the starter motor and rigidifying the outer housing of the starter motor.

[c2] 2. A starter for an internal combustion engine as set forth in claim 1, wherein the motor vibrations after engine starting are reduced by reducing the cogging torque of the starter motor.

[c3] 3. A starter for an internal combustion engine as set forth in claim 2, wherein the relationship between the pole cores facing ends and the permanent magnets is skewed to reduce the cogging torque of the starter motor.

[c4] 4. A starter for an internal combustion engine as set forth in claim 3, wherein the permanent magnets are skewed relative to the axis of relative rotation and the pole cores are not.

[c5] 5. A starter for an internal combustion engine as set forth in claim 4, wherein the magnetization of the permanent magnets is skewed but their shape is not.

[c6] 6. A starter for an internal combustion engine as set forth in claim 4, wherein the edges of the permanent magnets are skewed but their magnetization is in the direction of the axis of relative rotation.

[c7] 7. A starter for an internal combustion engine as set forth in claim 6, wherein the edges of the permanent magnets are curved to provide curved gaps therebetween.

[c8] 8. A starter for an internal combustion engine as set forth in claim 7, wherein the facing edges of the permanent magnets are respectively concave and convex to provide a constant width in the gap therebetween.

[c9] 9. A starter for an internal combustion engine as set forth in claim 4, wherein each of the permanent magnets is comprised of axially spaced and circumferentially spaced but circumferentially overlapping segments.

[c10] 10. A starter for an internal combustion engine as set forth in claim 9, wherein each permanent magnet is comprised of only two segments.

[c11] 11. A starter for an internal combustion engine as set forth in claim 9, wherein each permanent magnet is comprised of an uneven number of segments consisting of a center segment and side segments circumferentially spaced from said center segment but circumferentially overlapping said center segment.

[c12] 12. A starter for an internal combustion engine as set forth in claim 11, wherein there are more than one side segment on each side of the center segment and the side segments on each side are circumferentially spaced from each other.

[c13] 13. A starter for an internal combustion engine as set forth in claim 3, wherein the pole cores are skewed relative to the axis of relative rotation and the permanent magnets are not.

[c14] 14. A starter for an internal combustion engine as set forth in claim 13, wherein the cores are laminated and the laminations are circumferentially spaced from each other but in overlapping relationship.

[c15] 15. A starter for an internal combustion engine as set forth in claim 1, wherein the motor vibrations after engine starting are reduced by rigidifying the outer housing of the starter motor.

[c16] 16. A starter for an internal combustion engine as set forth in claim 15, wherein the motor outer housing comprises a central yoke portion carrying the permanent magnet element and closed by end closures.

[c17] 17. A starter for an internal combustion engine as set forth in claim 16, wherein

the outer housing is rigidified by a rigidifying member fixed relative to and engaging said central yoke portion.

- [c18] 18. A starter for an internal combustion engine as set forth in claim 17, wherein the rigidifying member also functions as a mounting bracket for said starter.
- [c19] 19. A starter for an internal combustion engine as set forth in claim 18, wherein the mounting bracket is directly affixed to the central yoke portion.
- [c20] 20. A starter for an internal combustion engine as set forth in claim 17, wherein the rigidifying member is directly affixed to the end closures and is in abutting relation to the central yoke portion.
- [c21] 21. A rotating electrical machine of reduced cogging torque comprised of cooperating, relatively rotatable permanent magnet and coil winding elements, said permanent magnet element being comprised of circumferentially spaced permanent magnets of opposite polarity, said coil winding element being comprised of circumferentially spaced magnetic pole cores around which electrical coils are wound, said cores having ends in facing relation to said permanent magnets, the relationship between said pole cores facing ends and said permanent magnets being skewed to reduce the cogging torque of the starter motor, the edges of said permanent magnets are curved to provide curved gaps therebetween and to effect the skewing.
- [c22] 22. A starter for an internal combustion engine as set forth in claim 21, wherein the facing edges of the permanent magnets are respectively concave and convex to provide a constant width in the gap therebetween.
- [c23] 23. A rotating electrical machine of reduced cogging torque comprised of cooperating, relatively rotatable permanent magnet and coil winding elements, said permanent magnet element being comprised of circumferentially spaced permanent magnets of opposite polarity, said coil winding element being comprised of circumferentially spaced magnetic pole cores around which electrical coils are wound, said cores having ends in facing relation to said permanent magnets, the relationship between said pole cores facing ends and said permanent magnets being skewed to reduce the cogging torque of the

starter motor, each of said permanent magnets being comprised of axially spaced and circumferentially spaced but circumferentially overlapping segments to effect the skewing.

- [c24] 24. A starter for an internal combustion engine as set forth in claim 23, wherein each permanent magnet is comprised of only two segments.
- [c25] 25. A starter for an internal combustion engine as set forth in claim 23, wherein each permanent magnet is comprised of an uneven number of segments consisting of a center segment and side segments circumferentially spaced from said center segment but circumferentially overlapping said center segment.
- [c26] 26. A starter for an internal combustion engine as set forth in claim 25, wherein there are more than one side segment on each side of the center segment and the side segments on each side are circumferentially spaced from each other.